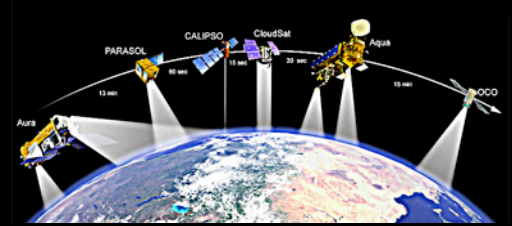




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Understanding the Earth System in a Changing World

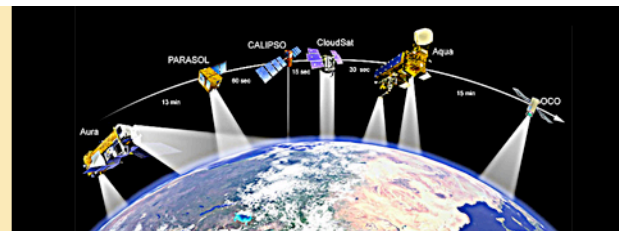
Exploring the Scientific and Historical Foundations of Earth System Science

June 22, 2009

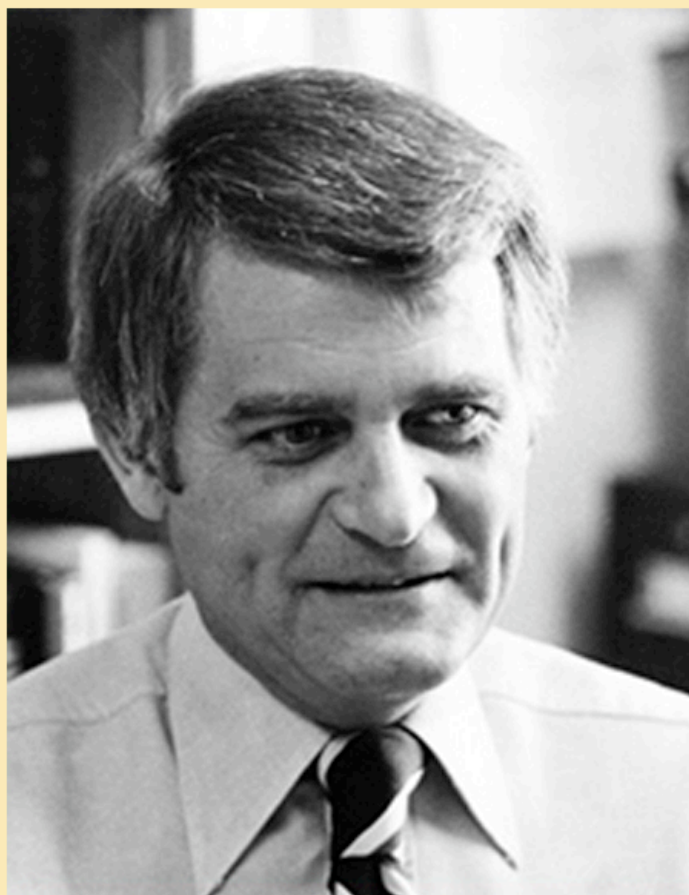
Dr. Robert W. Corell



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Remembrances



Dr. Jack Eddy

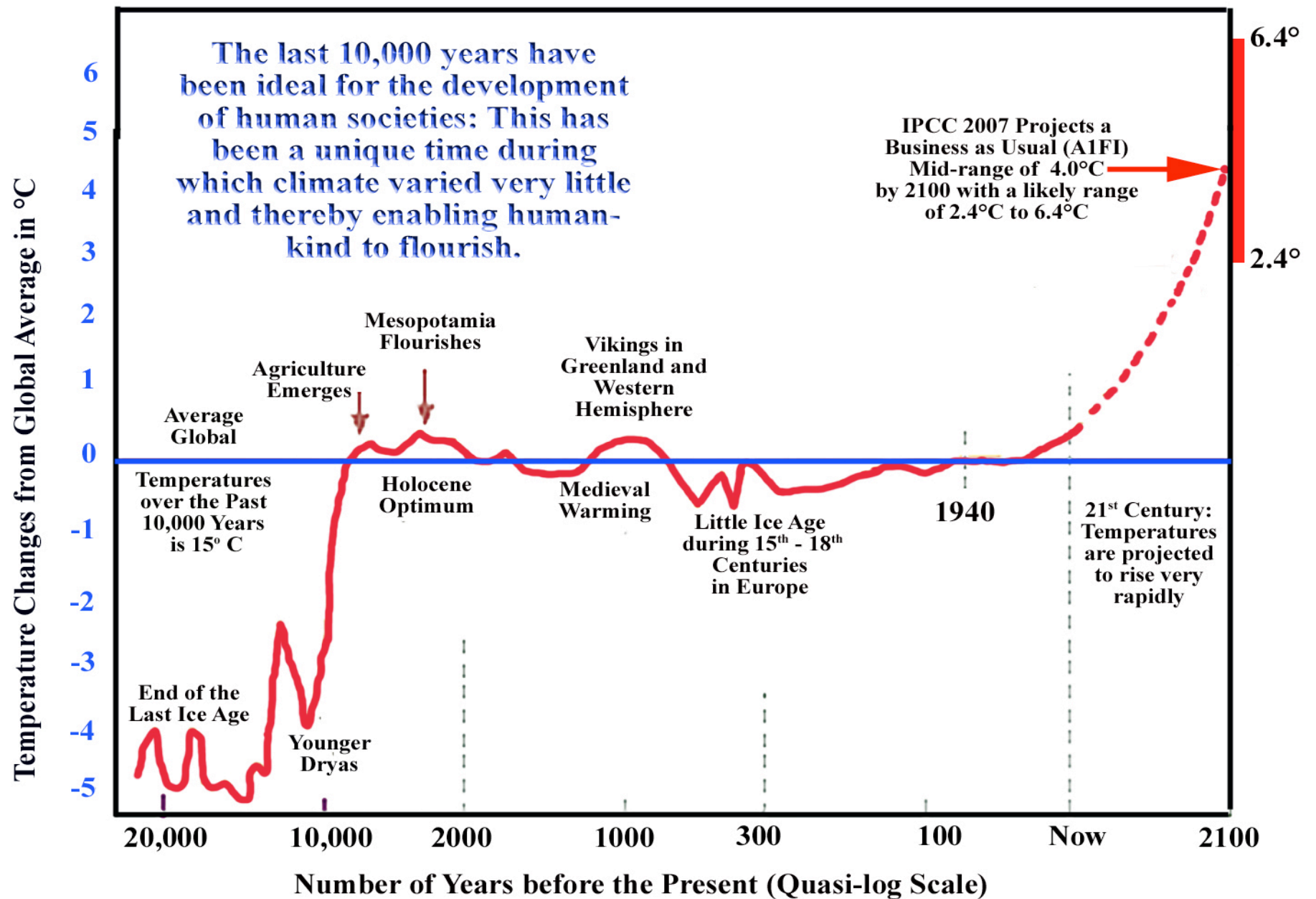
The challenge:

“The stakes are high. Climate change has profound implications for virtually all aspects of human well being, from jobs and health to food security and peace within and among nations.

Yet too often climate change is seen as an environmental problem when it should be part of the broader development and economic agenda.

Until we acknowledge the all-encompassing nature of the threat, our response will fall short.”

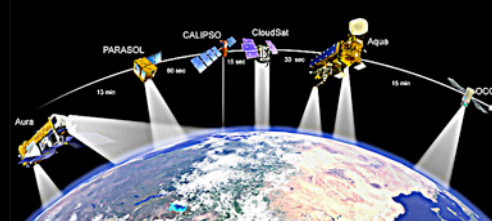
Kofi Anan. Former Secretary General of the United Nations



Source: Adapted from "Climate change and human health - risks and responses" published by WHO in collaboration with UNEP and WMO 2003 and more recent data from IPCC 2007.



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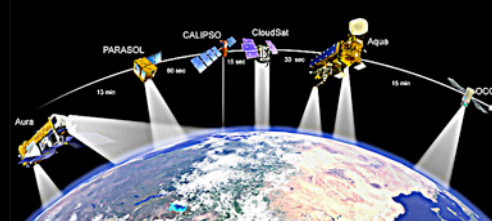


What are some of the origins of this human passion to want understand the large-scale behavior of our planet?

- During the Enlightenment (~ 17th Century), Abbe Du Bos, believed that “*the rise and fall of cultures was linked to changes in climate.*”
- Joseph Fourier, in 1824, alludes to the “*greenhouse effect*” in one of his scientific papers.
- In 1859, John Tyndall, wrote that, “*the atmosphere admits of the entrance of the solar heat, but checks its exit; and the result is a tendency to accumulate heat at the surface of the planet.*”
- For many, our perspectives on the Earth system and climate began with in 1896 by Professor Svante August Arrhenius when he calculated that emissions from human industry might someday bring a “*global warming.*”



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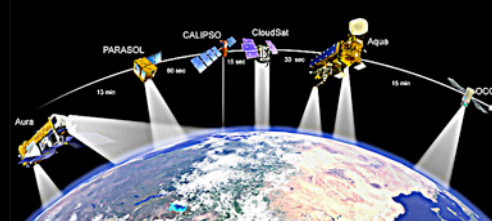


A key benchmark in the evolution of the concepts that lead to the need to understand the large-scale behavior of our planet was when Roger R. D. Revelle, who along with Hans Suess, stated:

“Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future. Within a few centuries we are returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years. This experiment, if adequately documented, may yield a far reaching insight into the processes determining weather and climate.”



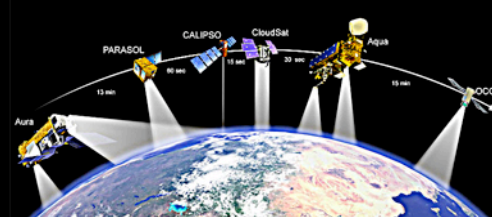
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- **The linchpin in the evolution that lead directly to the concepts we now call “Earth System Science” is the seminal work in 1983 with the establishment and foundational work of the NASA Advisory Council’s Earth System Sciences Committee, chaired by Francis Bretherton.**
- **When they published their seminal report in 1988, “*Earth System Science: A Program For Global Change.*” they showed for the first time how the many components of the Earth systems interact which they depicted in the now famous “Bretherton Diagram.”**



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The Goal:

“The goal of earth system science is to obtain a scientific understanding of the entire earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales.”

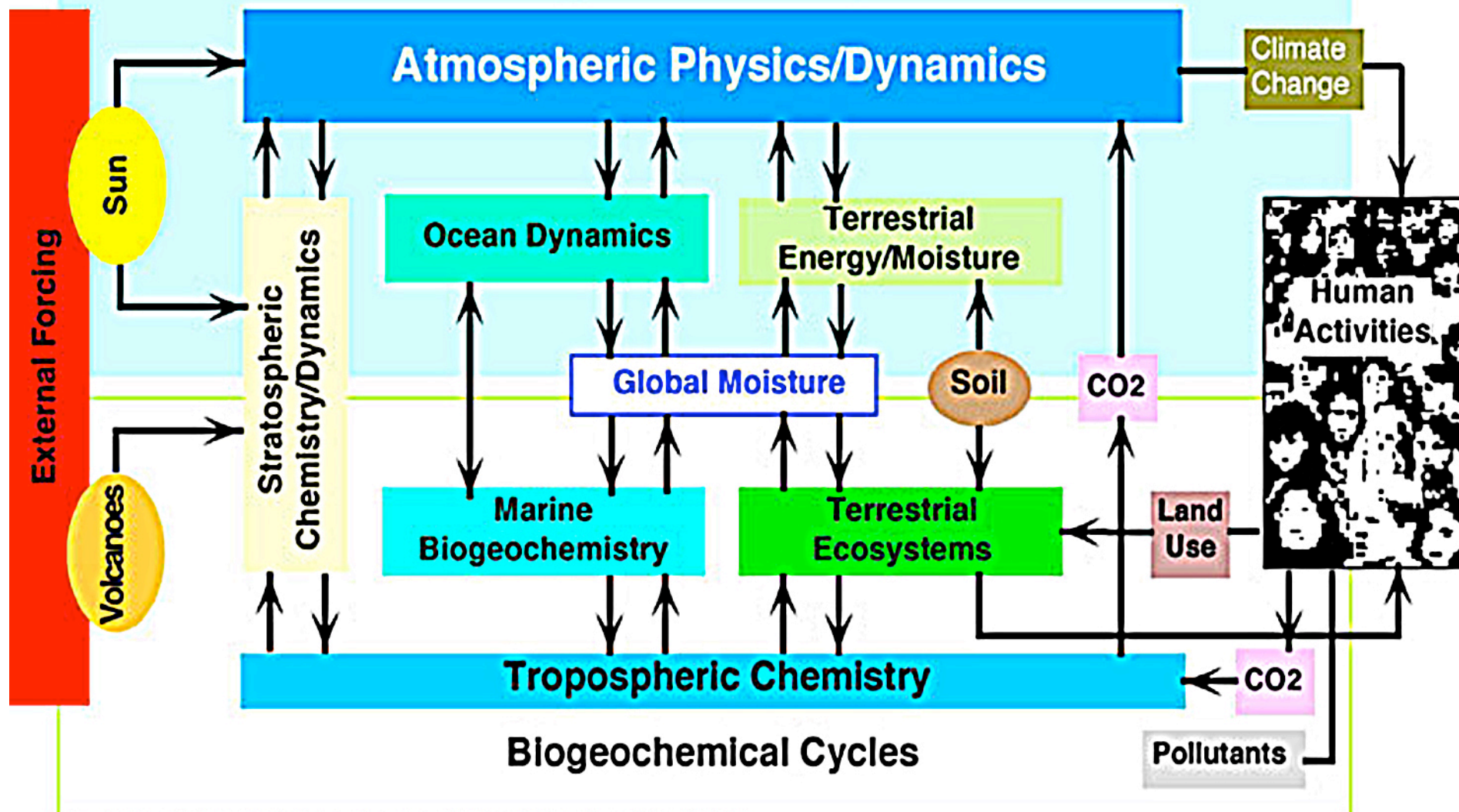
From Earth System Science Committee (1986). Overview, page 26.



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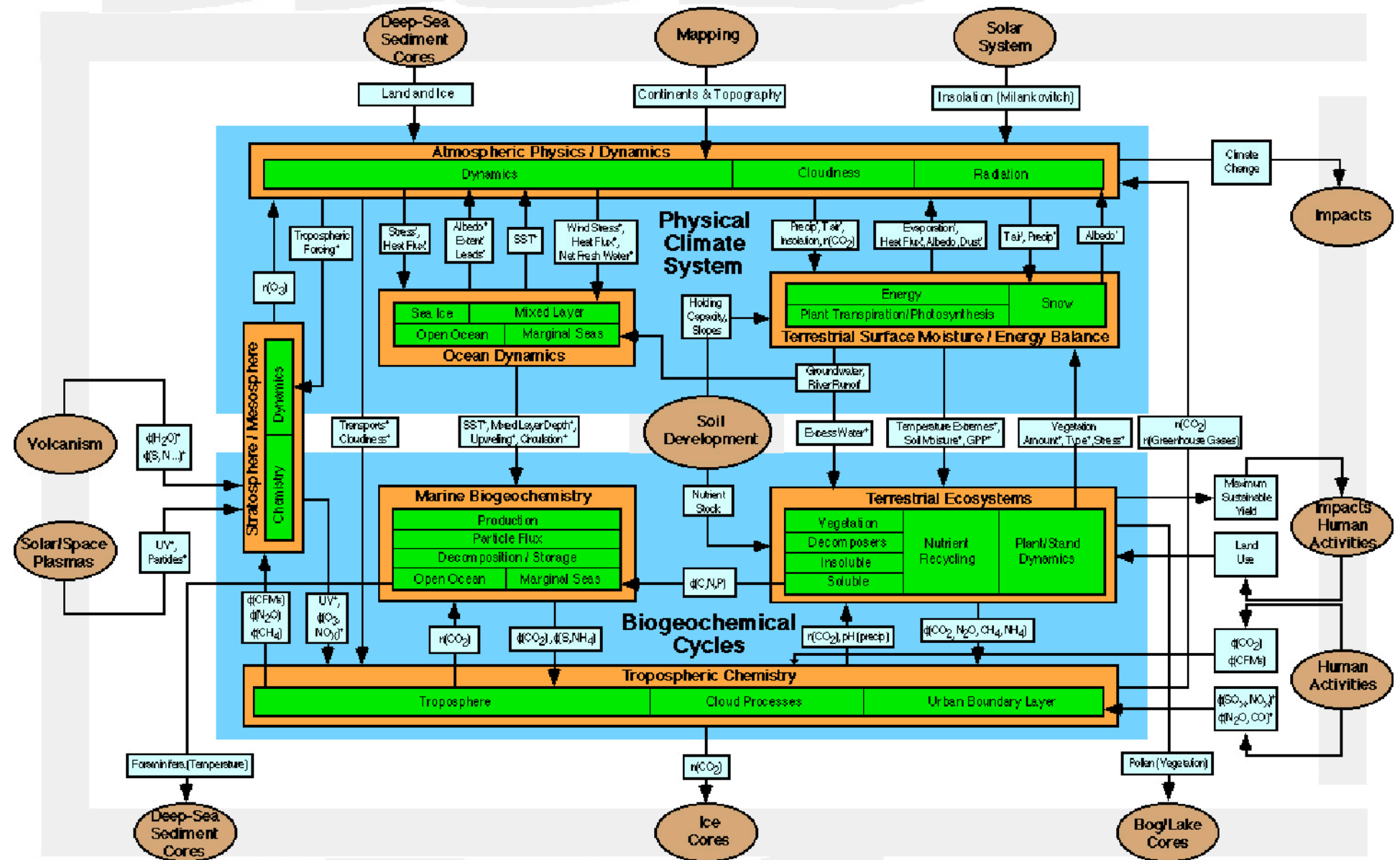


Physical Climate System



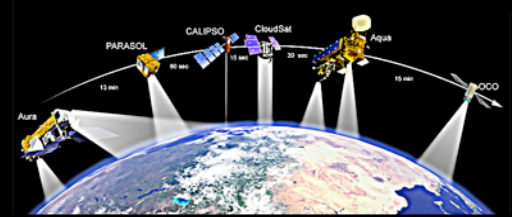
(from Earth System Science: An Overview, NASA, 1988)

An Evolution of the “Bretherton Diagram” that Depicts the Various Components of the Earth System in Expanded Detail





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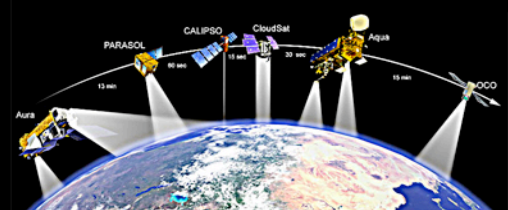


The USGCRP was established in 1989, and was included as a Presidential Initiative in the FY90 budget as a high-priority research effort, designed to:

- **Address key uncertainties about changes in the Earth system, both natural and human-induced.**
- **Monitor, understand, and predict global change.**
- **Provide a sound scientific basis for national and international decision-making on global change issues.**



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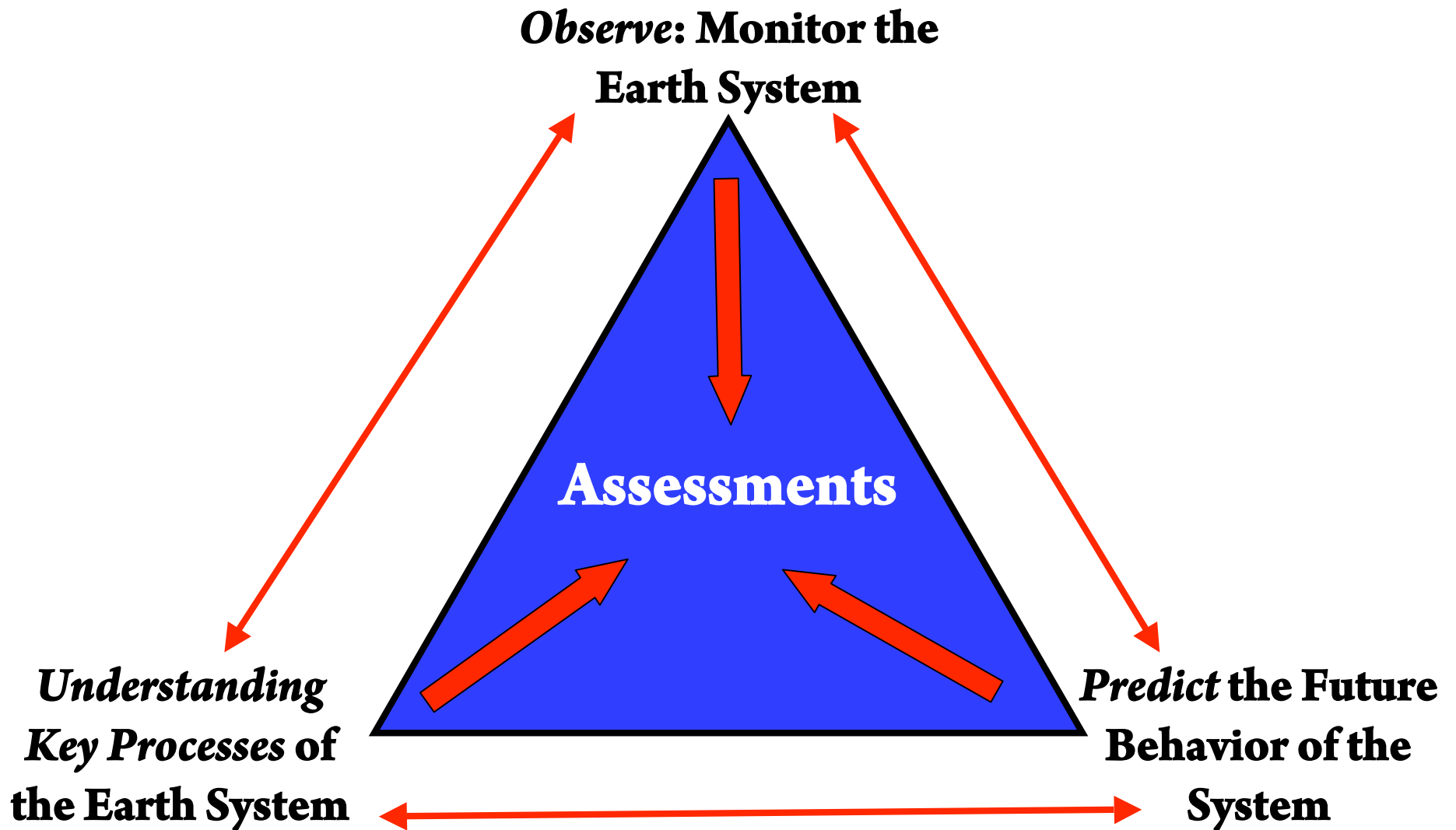
The USGCRP was established in 1989 in 1990 Congress codified the USGCRP in the Global Change Research Act of 1990, in order to provide for:

- "...development and coordination of a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."
- "...increasing the overall effectiveness and productivity of Federal global change research efforts."

The Global Change Research Act defines global change as:

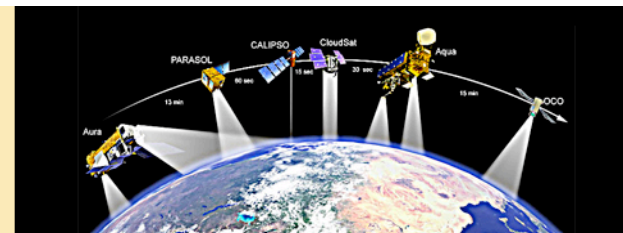
- "changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life."

This Diagram Drove Many Discussions on Scientific and Program Integration

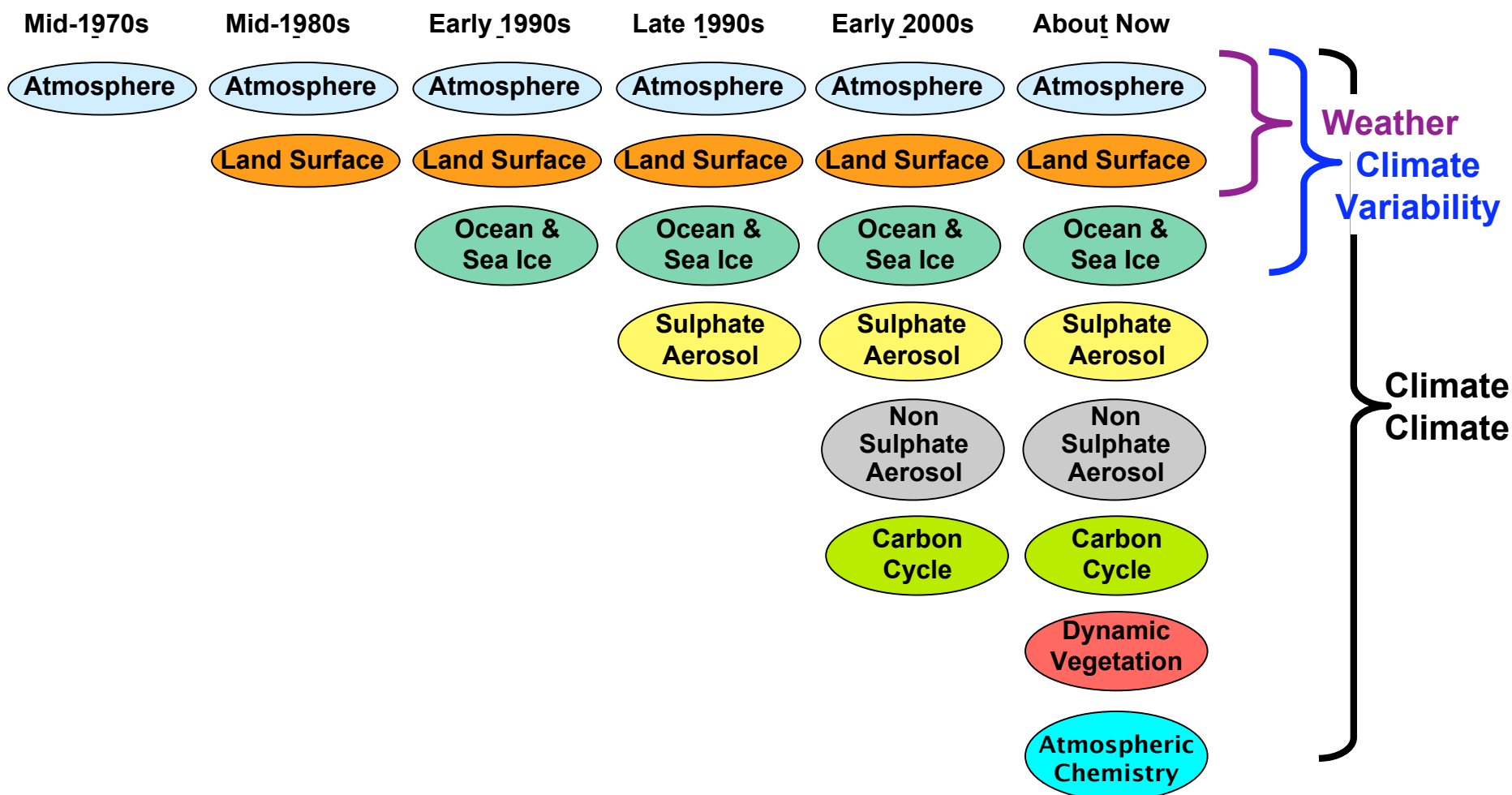




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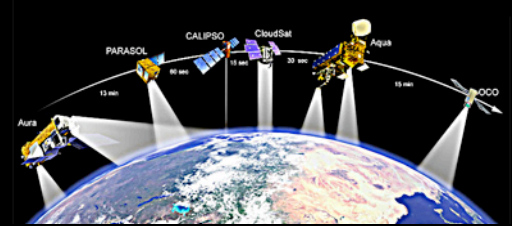


An Evolution of the Modeling that Evolved from the “Bretherton Era” and an Interest to Simulate the Behavior of the Earth System





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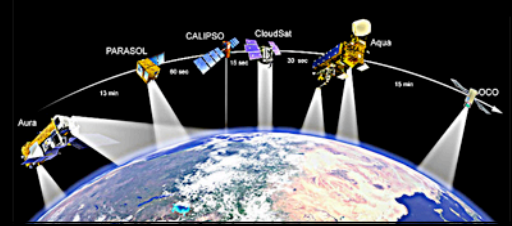


Some Observations:

- **President Reagan and the Key “*Global Change*” Statement**
- **The early adoption of *Earth System Science: A Program For Global Change* construct, which became key initiatives at NASA and then NSF and NOAA**
- **The transition from the Reagan Era to President Bush 41 where it became a very high priority in that Administration with major joint leadership at OSTP and OMB, and the engagement of the earth sciences community under this mantra of Earth System Science.**
- **The Appointment of NAS Study Committees, Boards and Panels**
- **The early creation of an interagency process with major support from the Administration and the use of the FCCSET as the oversight venue.**



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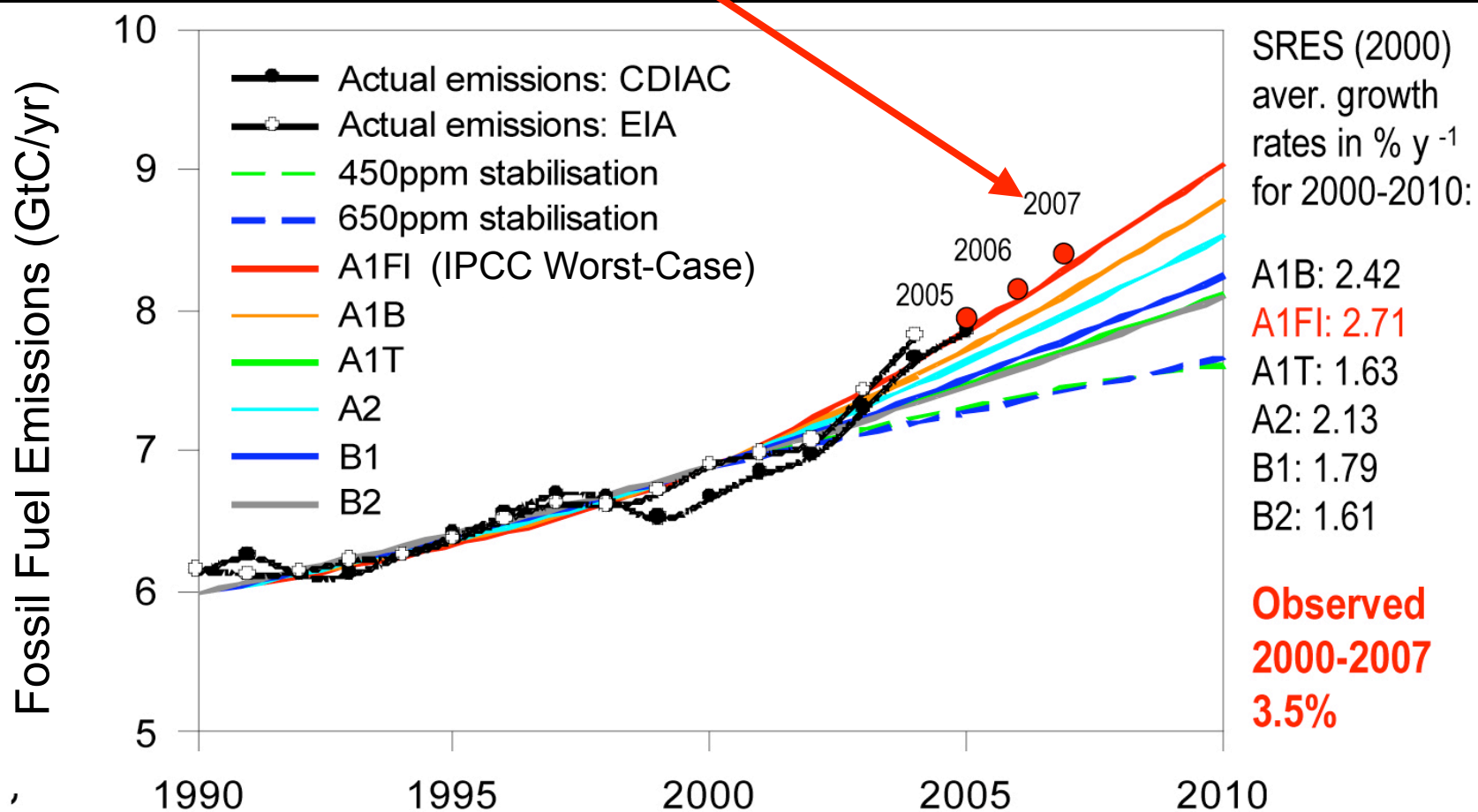


Some Observations:

- **The partnership between OMB and OSTP was and remains critical, and the issuance of the Joint Annual Budget Memo**
- **The requirement that a USGCRP Budget be created, following the directives of the Joint Memo and that it be submitted as a part of the President Annual Budget message to the Congress was crucial**
- **The partnership with all the USGCRP Agencies and departments, which started with 14 and grew over time to 18, with similar partnership abroad (CEOS, WCRP, IGBP, IHDP, DIVERATAS, etc)**
- **What made the difference, was a shared vision of the challenges of a rapidly changing planet and the potential impacts on the Earth's natural systems and therefore all humankind**

Fossil Fuel Emissions: Actual vs. IPCC Scenarios

We face an incredible challenge: Emissions now exceed the IPCC Worst-case Scenario.



Atmospheric CO₂ Concentration

**Year 2008
Atmospheric CO₂
Concentration:**

387 ppm

~ 40% above pre-industrial

Growth in Atmospheric CO₂ Concentrations/Year:

1970 - 1979: 1.3 ppm/year

1980 - 1989: 1.6 ppm/year

1990 - 1999: 1.5 ppm/year

2000 - 2007: 2.0 ppm/year

2007: 2.2 ppm/year

2008: 2.3 ppm/year

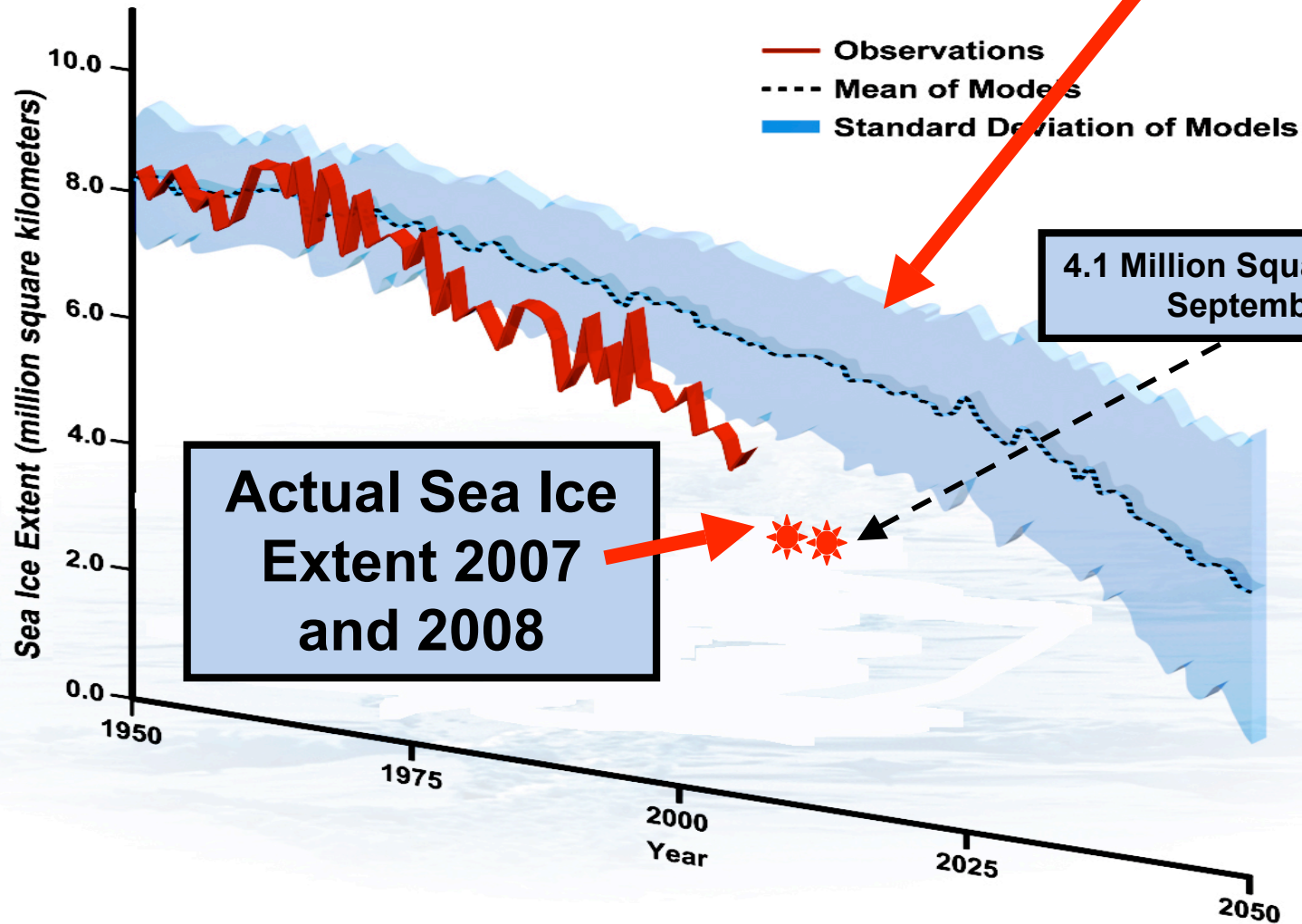
**At this
accelerating
rate we will be
at 500 ppm by
2050**

Accelerating

Recent Findings:

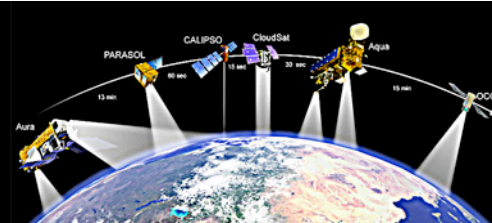
Arctic September Sea Ice Extent: Observations and Model Runs

**ACIA Model
Projections
in 2004**

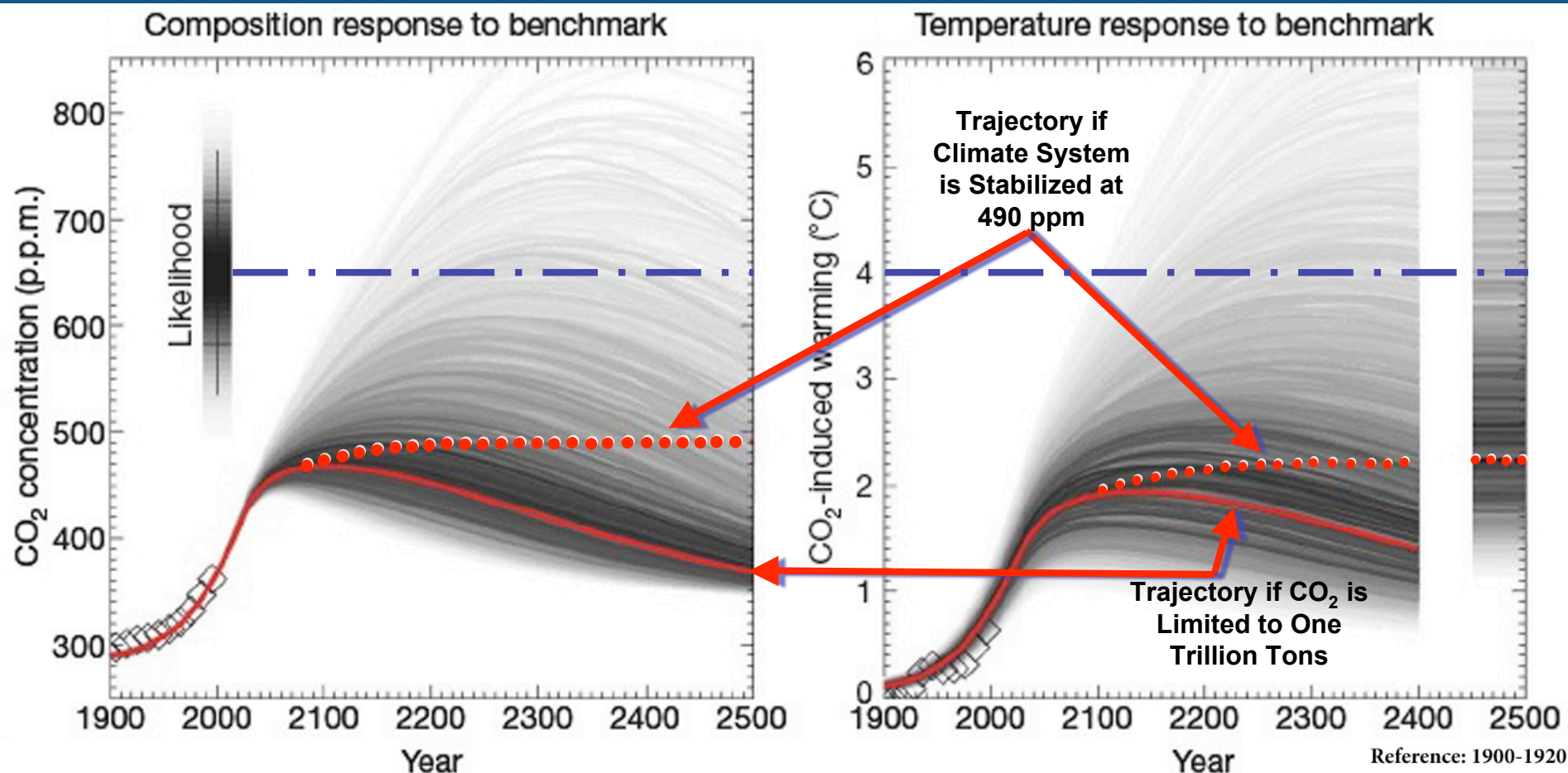




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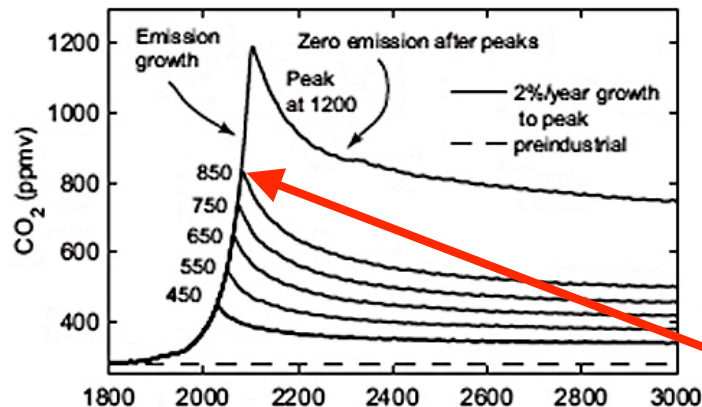


Multi-Century Implications of CO₂ on the Behavior of Climate System

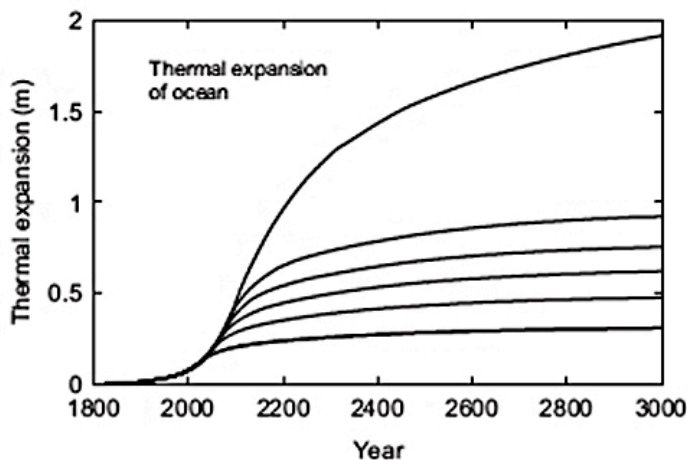
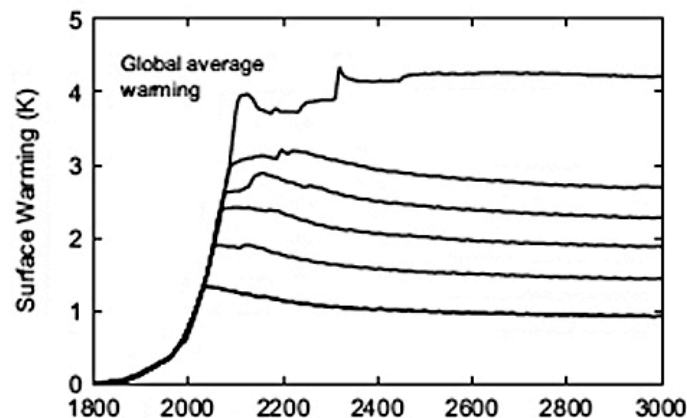


Source: Warming caused by cumulative carbon emissions towards the trillionth tonne. Myles R. Allen et al, Science, 2009

The Millennium-Scale Challenges Climate Change due to Carbon Dioxide Emissions



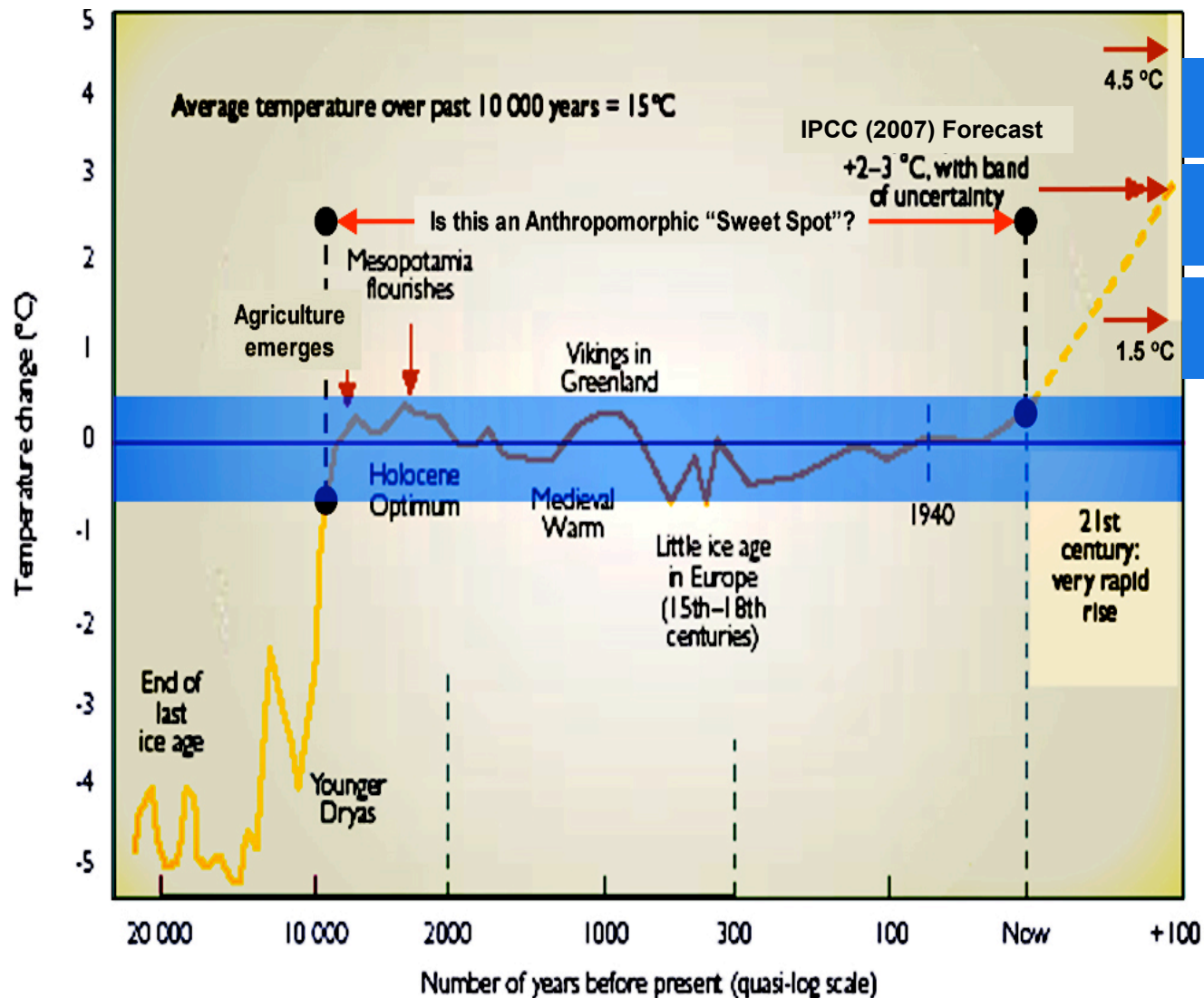
Note: Emissions grow until 2100 and stop thereafter.



The severity of damaging human-induced climate change depends not only on the magnitude of the change but also on the potential for irreversibility. Solomon et al show that the climate change that takes place due to increases in carbon dioxide concentration is largely irreversible for 1,000 years after emissions stop.

Source: Irreversible climate change due to carbon dioxide emissions Susan Solomon et al PNAS 2009;

The question is: At what temperature will we stabilize?



750 ppm ~ 4.3 °C

550 ppm ~ 3 °C

450 ppm ~ 2 °C

There is the potential that the climate is likely, as projected by the IPCC, to take humankind where it has never been

*The Earth System
Science Construct
has been an
incredible framing
for the relevant
scientific challenges!*

This pale blue dot is planet Earth taken from Saturn by NASA's Cassini spacecraft looking back toward the Earth on Sept. 27, 2006. Saturn is about 800 million miles from the Earth.



Thank You !